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The relation of cyclophoria to the difference between monocularly and binocularly measured axes of astigmatism at near.

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The purpose of this research project is to determine the role cyclophoria plays when considering the differences between a monocular and a binocular refraction at forty centimeters. We are under the assumption that the eye is in its cyclophoric position while undergoing the monocular phase of the test, and is in its non-cyclophoric position while undergoing the binocular phase of the test. It was our contention that cyclophoria does exist and would play some role in the differences between a monocular and a binocular refraction. As a result, we would hypothesize that the rotation of the cylinder axes between the two refractions should correspond closely to the rotation of cyclophoria. ifuat our project has found is that cyclophoria does definitely play a role in the shift in axis from a binocular to monocular refraction, but this role varies in magnitude in each individual subject. The optometric implications of this research become significant when we consider patients who require astigmatic corrections, where a routinely monocularly refracted cylinder power and axis is prescribed, but where a different binocularly refracted cylinder power and axis might be more useful, since we function in this binocular mode the majority of the time. Our findings would suggest that this situation could exist in many cases, especially when cylinder powers are significant, and there is less tolerance for an imprecise axis measurement.

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The Relation of Cyclophoria to the Difference Between Monocularly and Binocularly Measured Axes of Astigmatism at Near.

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Introduction

Cyclophoria may be defined as the relative orientation of the two eyes about their respective lines of sight in the absence of cyclofusional stimuli.[1] According to Scobee[2], it is probably less understood and less discussed than any other organic or functional motor anomaly of the eye.

The significance of cyclophoria may come into play when we consider patients wearing some amount of cylinder correction in their prescriptions. Under most normal circumstances, a patient with astigmatism is refracted monocularly at distance, but wears that prescription under binocular conditions and also at different working distances. Many advocates of the binocular refraction have found that cylinder powers and axes often change from the monocular refraction, where the patient is under his or her phoric condition (lateral, vertical, and cyclo), compared to a binocular refraction, where the patient is not under these phoric influences. Both Grolman[3] and Miles[4] have found cylinder axis differences averaging about eight degrees between monocular and binocular refractions. Scobee[2] found alterations amounting to as much as ten degrees. Between distance and near point, Bannon[5] found that 50 percent of his subjects showed a difference of at least .25 D., of these, fourteen percent demonstrated a difference equal to at least .50 D. For 34 percent of those subjects with at least 1.00 D. of cylinder, the average axis at near differed from that at distance by at least five degrees.

The shift in axis from a monocular to binocular refraction could be due to a number of reasons. Hughes[6] concluded that the cause is presumed to be a sector weakness of the suspensory fibers of the lens, since he saw no abnormal tension of the eye from the extrinsic muscles with a microscope and an ophthalmometer. Contradicting Hughes, Pascal[7] hypothesized that tension caused by the action of the extrinsic muscles in near vision slightly changed the curves of the cornea. He concluded that the degree of this muscular tension is not likely to be the same at different times, and different degrees of muscle tension would produce slightly different effects. Sugar[8] stated that the cause of the shift in axis could be due to four mechanisms: 1) lenticular changes (Hughes), 2) fusional compensation of the binocular vision, 3) torsional movements of the globe (cyclophoria), and 4) actions of the extrinsic muscles in near vision slightly changing the curves of the cornea (Pascal).

Concentrating specifically on the cyclophoric component of the shift in axes of astigmatism, Allen[9] reviewed the results of Landolt, Hering, Donders, Carow, and Hermans and their individual works in cyclophoria. Three major conclusions that he arrived at were: 1) Cyclophoria is always associated with convergence except at a position of depression of around 30-35 degrees. 2) Although at zero degree elevation and a 40 cm. working distance, about two to three degrees of cyclophoria could be found, cyclophoria values as high as 16 degrees at extreme positions of elevation and convergence may be obtained. 3) Cyclophoria associated with convergence can be an important factor in the measurement of meridional aniseikonia and in the location of the axis of astigmatism.

Shreve[10] also felt a great need to consider cyclophoria in his refractions and subsequently developed a method for a binocular refraction that would eliminate any cyclophoria influencing his results. It involved testing astigmatism of one eye with a monochromatic red chart, while the other eye is denied a view of this chart by a red-free (greenish-blue) filter, but is allowed sufficient vision of the surrounding field to provide binocular fusion.

One must wonder how significant a role cyclophoria plays in the differences between a monocular and binocular refraction, compared to the other factors. We will determine this role of cyclophoria by quantifying the amount and direction of cyclophoria present utilizing Maddox rods and a biprism, and comparing that amount and direction of cyclophoria to a change in axis between a monocular and binocular Pratt near cylinder test. If cyclophoria does play a dominant role, then the amount and direction of cyclophoria in each eye should correlate closely with the amount and direction of change in axis from a binocular Pratt near cylinder test to a monocular Pratt near cylinder test, since it is in the monocular test where the two eyes are in their cyclophoric position.

Experimental Methodology

From fifty selected Pacific University optometry students aged 23 to 35, one-hundred eyes of at least .50 D. cylinder refractive error were tested by the following procedure:

1) A Bausch and Lomb Greens phoropter was preset with the subject's habitual Rx. for 40 cm. and near PD.
2) Cyclophoria Measurement:
   A) A biprism was taped before the left eye in front of the clear Maddox rod aligned at zero degrees on the B and L Greens phoropter, with the base line of the biprism placed horizontally. The red Maddox rod alone was aligned at zero degrees and was placed in front of the right eye, which was the eye under test. A transilluminator placed at 40 cm. at the midline and shined into the direction of the subject's eyes resulted in the subject observing two white horizontal lines and one red horizontal line between the two white lines. The red Maddox rod was rotated 10 degrees out of position counter-clockwise (overcorrecting excyclorotation) and slowly returned clockwise until the subject responded that all three lines were parallel. The sequence was repeated one time to check for consistency, and an average value recorded. The amount of rotation was read off of the red Maddox rod, and was the amount of cyclophoria in the right eye. It was labelled excyclophoria or encyclophoria depending on which side of vertical the zero point was positioned. (See figure 1).
   B) The same test was repeated with the biprism taped before the right eye. This time the clear Maddox rod was rotated 10 degrees out of position clockwise and slowly returned

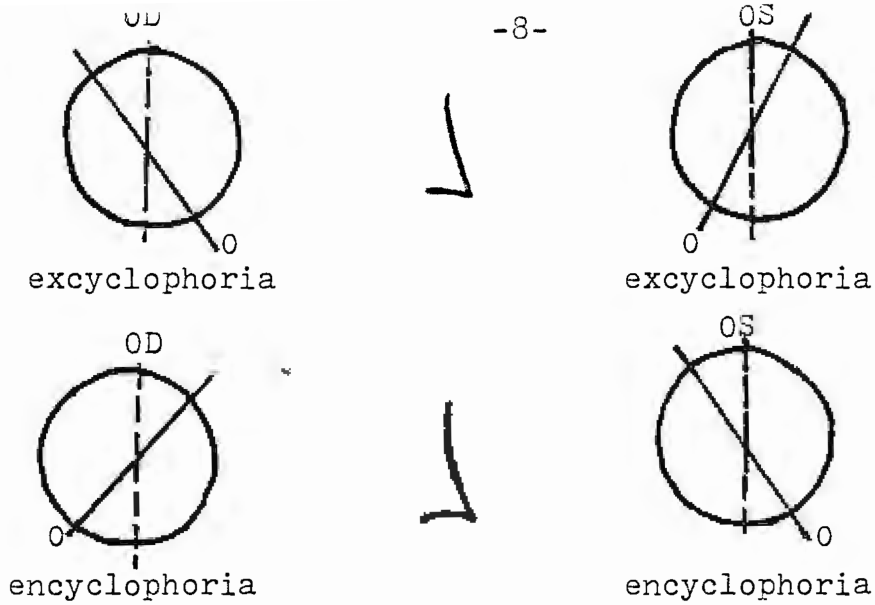

Figure 1. Placement of the zero point determines excyclophoria or encyclophoria.

counter-clockwise, with the red Maddox rod aligned at zero degrees to measure the amount of cyclophoria in the left eye.

3) The two Maddox rods were taken away and a #21 monocular to blur out then recovery utilizing 20/20 reduced Snellen letters was performed over each eye and the recovery amount used as a preset for the Pratt near cylinder tests.

4) A monocular Pratt near cylinder test utilizing the 45^{o}-135^{o} and 90^{o}-180^{o} cross-grids was performed over each eye, with the end-point being the near cylinder power and axis which made all lines of both cross-grids equally dark.

5) A binocular Pratt near cylinder test utilizing a polarizing over-lay clipped on the two cross-grid targets was performed (see figure 2). With correct orientation of the overlay, a pair of polarizing glasses were worn by the subject that enabled him or her to see the target only through one eye, although both eyes were open, thus making the borders of the card and clips a fusion lock. The binocular Pratt near cylinder test was run with just the right eye seeing the target and then with just the left eye seeing the

target, with the same endpoints as in part 4).

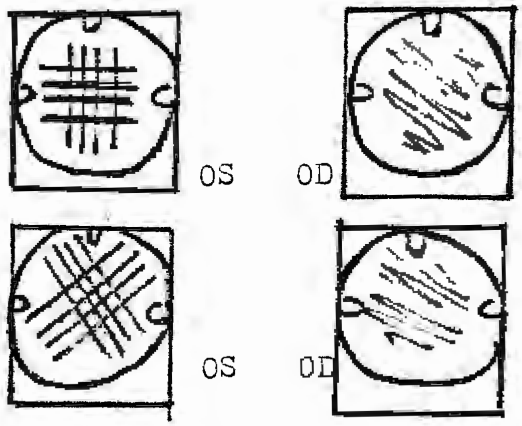

Figure 2. Polarizing filter placed over cross-grid targets at proper orientation to be visible to one eye and not the other.

Consideration of the Variables

Although the data collected by the experimental methods described in the previous section were gathered as carefully and meticulously as possible, it should be kept in mind that certain variables could be controlled for, while others could not.

A major variable to be considered must be the subjects' sensitivity to the Pratt near cylinder tests, especially when determining the axis changes. The tendency was for the subjects with lower amounts of cylinder power to be less sensitive than those with higher amounts of cylinder. In other words, a greater amount of axis "rocking" had to be done with the low cylinder powers than with the high cylinder powers. In order to compensate for this, we grouped our subjects by cylinder power in the data analysis section forthcoming.

Also a major variable to consider was experimenter bias while collecting the data. Although the data was collected in the same order of sequence through the fifty subjects, the experimenter was blind to what constituted a "correct" response of the subject (excyclophoria combined with an excyclorotation of the axis and encyclophoria combined with an encyclorotation of the axis). This was because the direction of the "correct" responses differed whether the left or the right eye was under test. Also, in the binocular portion of the refraction, the first eye tested was randomly chosen depending on which way the polarizing overlay was reassembled and oriented by the experimenter.

Other variables included the use of more than one particular Bausch and Lomb phoropter because of prior clinic or procedures laboratory use when subjects were scheduled. The phoropters in room B7 and station 8 in the "c" room were utilized most often with occasional use of the phoropters in rooms A3 and B2. Of concern in these cases were the possibly different orientations of the Maddox rods at the zero position. To insure the validity of the findings, the experimenter visually inspected the Maddox rods prior to testing subjects to make certain that the zero point on the Maddox scale aligned with the 90° mark on the phoropter when the Maddox rods were set in position. Variables in lighting at each of the different phoropters also were not considered.

With regards to the cyclophoria measurements, precision of the readings were limited because the Maddox rods were marked only at 5° intervals. The experimenter estimated as accurately as possible, the majority of the measurements of cyclophoria to the closest degree. Unlike the cylinder axis measurements, subject reliability was extremely high. The repeated measurement of the cyclophoria was always approximately the same rotation as the initial measurement. It is the experimenter's impression that the two findings were easily within 1° of each other according to his estimations.

Because the biprism had to be switched between eyes for every subject, the orientation of the biprism may have been varied from a precise horizontal position. To help insure validity, the experimenter carefully sighted from a straight-on position in front of the phoropter, that the prism line was parallel to the 180°-0° mark on the phoropter. Also, the polarizing overlay target had to be reassembled for each subject and that may have been varied from a set precise orientation to keep the target visible in one eye, and totally invisible in the other.

Results

The raw data collected are grouped according to the magnitude of refracted cylinder power for each eye. Tables I, II, and III, represent cylinder powers of 0 D. to -.75 D., -1.00 D. to -1.50 D., and -1.75 D. or more, respectively. Means and standard deviations of the shift in cylinder axis and amount of cyclophoria are shown with each table. In all cases, excyclorotation or excyclophoria is represented by a (+) sign, and encyclorotation or encyclophoria is represented by a (-) sign.

In figures 3, 4, and 5, the data from Tables I, II, and III, are plotted on a Cartesian coordinate graph with the x-axis representing the amount of cyclophoria in degrees, and the y-axis representing the change in cylinder axis from binocular to monocular refractions in degrees. It should be noted that in the last table where cylinder power was -1.75 D. or greater, and in the sum total, two different correlation coefficients were determined. One coefficient includes all points, while one coefficient excluded the two very deviant points labelled in red.

TABLE I: Cylinder power 0 D. to -.75 D.

subject	eye	mono. cyl.	bin. cyl.	change cyl. ax.	cyclo.
1	OD	-.50x001	-.50x171	+10°	+3°
1	OS	-.75x016	-.75x020	+4°	+3°
2	OD	-.50X008	-.50x017	-9°	+3°
2	OS	-.50x180	-.50x010	+10°	+2°
10	OD	-.50x012	-.50x012	0°	0°
10	OS	-.75x180	-.75x003	-3°	+1°
11	OD	-.50x081	-.50x078	+3°	+3°
12	OD	-.75x127	-.75x118	+9°	+3°
12	OS	-.75x013	-.75x008	-5°	+3°
13	OD	-.50x175	-.50x174	+1°	+5°
13	OS	-.50x170	-.50x175	+5°	+5°
14	OD	-.75x180	-.75x170	+10°	+2°
14	OS	-.50x020	-.50x029	+9°	+2°
17	OD	-.50x060	-.50x057	+3°	+2°
17	OS	-.75x180	-.75x006	+6°	+2°
18	OD	-.75x009	-.75x014	-5°	+2°
18	OS	-,75x148	-.75x136	-8°	+3°
21	OD	-.75x002	-.75x180	+2°	+4°
21	OS	-.50x060	-.50x060	0°	+3°
23	OD	-.50x180	-.50x180	0°	+2°
23	OS	-.50x005	-.50x006	+1°	+1°
26	OD	-.75x178	-.75x179	-1°	+4°
26	OS	-.75x006	-.75x009	+3°	+4°
27	OD	-.75x131	-.75x127	+4°	+3°
27	OS	-.75x044	-.75x038	-6°	+2°
28	OD	-.50x046	-.50x046	0°	+2°
28	OS	-.50x122	-.50x122	0°	+2°
29	OD	-.75x130	-.75x130	0°	+2°
29	OS	-.50x044	-.50x050	+6°	+3°
30	OD	-.50x006	-.50x009	-3°	0°
32	OD	-.50x145	-.50x145	0°	+1°
32	OS	-.50x009	-.50x007	-2°	+2°
35	OS	-.50x012	-.50x014	+2°	+2°
36	OD	-.50x165	-.50x162	+3°	0°
40	OS	-.75x085	-.75x085	0°	0°
41	OD	-.50x045	-.50x045	0°	-2°
41	OS	-.50x148	-.50x148	0°	0°
43	OD	-.50x167	-.50x168	-1°	+1°
43	OS	-.50x180	-.50x180	0°	+1°
50	OD	-.75x179	-.75x005	-6°	-2°

n=40		
mean	+1.05°	+1.975°
S.D.	4.76	1.58

TABLE II: Cylinder power -1.00D. to -1.50D.

subject	eye	mono. cyl.	bin. cyl.	change cyl. axis	cyclo.
3	OD	-1.00x089	-1.00x091	-2°	$+1^{\circ}$
3	OS	-1.00x089	-1.00x081	-8°	0°
4	OD	-1.50x173	-1.50x173	0°	$+1^{\circ}$
4	OS	-1.50x009	-1.50x009	0°	$+1^{\circ}$
6	OD	-1.50x160	-1.50x159	$+1^{\circ}$	$+4^{\circ}$
7	OD	-1.00x116	-1.00x118	-2°	$+1^{\circ}$
7	OS	-1.00x061	-1.00x055	-6°	$+1^{\circ}$
8	OD	-1.75x178	-1.50x001	-3°	$+2^{\circ}$
8	OS	-1.25x178	-1.50x173	-5°	$+3^{\circ}$
9	OD	-1.25x037	-1.50x033	$+4^{\circ}$	$+4^{\circ}$
9	OS	-1.25x135	-1.00x138	$+3^{\circ}$	$+5^{\circ}$
15	OD	-1.00x012	-1.00x006	$+6^{\circ}$	$+3^{\circ}$
15	OS	-1.00x178	-1.00x006	$+8^{\circ}$	$+3^{\circ}$
16	OD	-1.50x175	-1.50x173	$+2^{\circ}$	$+3^{\circ}$
16	OS	-1.50x180	-1.50x179	-1°	$+2^{\circ}$
19	OD	-1.50x007	-1.50x006	$+1^{\circ}$	$+1^{\circ}$
19	OS	-1.50x008	-1.50x010	$+2^{\circ}$	$+1^{\circ}$
20	OD	-1.50x020	-1.50x020	0°	$+2^{\circ}$
22	OD	-1.25x180	-1.25x002	-2°	$+1^{\circ}$
22	OS	-1.25x002	-1.25x179	-3°	$+1^{\circ}$
25	OS	-1.25x004	-1.25x007	$+3^{\circ}$	$+2^{\circ}$
30	OS	-1.25x178	-1.25x176	-2°	$+1^{\circ}$
31	OS	-1.25x094	-1.25x104	$+10^{\circ}$	$+3^{\circ}$
34	OS	-1.00x155	-1.00x156	$+1^{\circ}$	0°
35	OD	-1.00x004	-1.00x006	-2°	$+2^{\circ}$
36	OS	-1.50x005	-1.50x010	$+5^{\circ}$	-1°
37	OD	-1.25x180	-1.25x180	0°	$+2^{\circ}$
37	OS	-1.25x164	-1.25x164	0°	$+2^{\circ}$
40	OD	-1.25x085	-1.25x086	-1°	0°
42	OD	-1.50x175	-1.50x175	0°	$+2^{\circ}$
42	OS	-1.50x013	-1.50x017	$+4^{\circ}$	$+2^{\circ}$
44	OD	-1.50x002	-1.50x002	0°	0°
44	OS	-1.50x180	-1.50x180	0°	$+1^{\circ}$
45	OD	-1.50x002	-1.50x002	0°	0°
45	OS	-1.00x165	-1.00x156	-9°	0°
46	OD	-1.25x009	-1.25x006	$+3^{\circ}$	-2°
46	OS	-1.25x009	-1.25x010	$+1^{\circ}$	-2°
47	OD	-1.00x170	-1.00x170	0°	-1°
47	OS	-1.00x013	-1.00x015	$+2^{\circ}$	$+1^{\circ}$
50	OS	-1.00x083	-1.00x081	-2°	-2°

n=40		
mean	$+0.20^{\circ}$	$+1.25^{\circ}$
S.D.	3.75	1.61

TABLE III: Cylinder power -1.75 D. or more.

subject	eye	mono. cyl.	bin. cyl.	change cyl. axis	cyclo.
5	OD	-2,50x004	-2.50x001	+3°	+2°
5	OS	-2.50x180	-2.50x179	-1°	+4°
6	OS	-2.50x004	-2.50x004	0°	+2°
11	OS	-2.25x030	-2.25x023	-7°	+4°
20	OS	-1.75x175	-1.75x175	0°	+2°
24	OD	-2.50x010	-2.50x006	+4°	+4°
24	OS	-2.50x002	-2.50x004	+2°	+4°
25	OD	-1.75x174	-1.75x174	0°	+2°
31	OD	-1.75x161	-1.75x160	+1°	+3°
33	OD	-1.75x020	-1.75x017	+3°	+1°
33	OS	-2.25x165	-2.25x163	-2°	0°
34	OD	-1.75x006	-1.75x007	-1°	0°
38	OD	-2.00x162	-2.00x160	+2°	+1°
38	OS	-2.00x031	-2.00x030	-1°	+1°
39	OD	-2.50x030	-2.50x030	0°	+1°
39	OS	-2.50x160	-2.50x161	+1°	+2°
48	OD	-1.75x003	-1.75x178	+5°	+2°
48	OS	-1.75x178	-1.75x003	+5°	+2°
49	OD	-1.75x178	-1.75x172	+6°	-4°
49	OS	-1.75x008	-1.75x005	-3°	-3°

n=20		
mean	+0.85°	+1.50°
S.D.	3.08	2.11

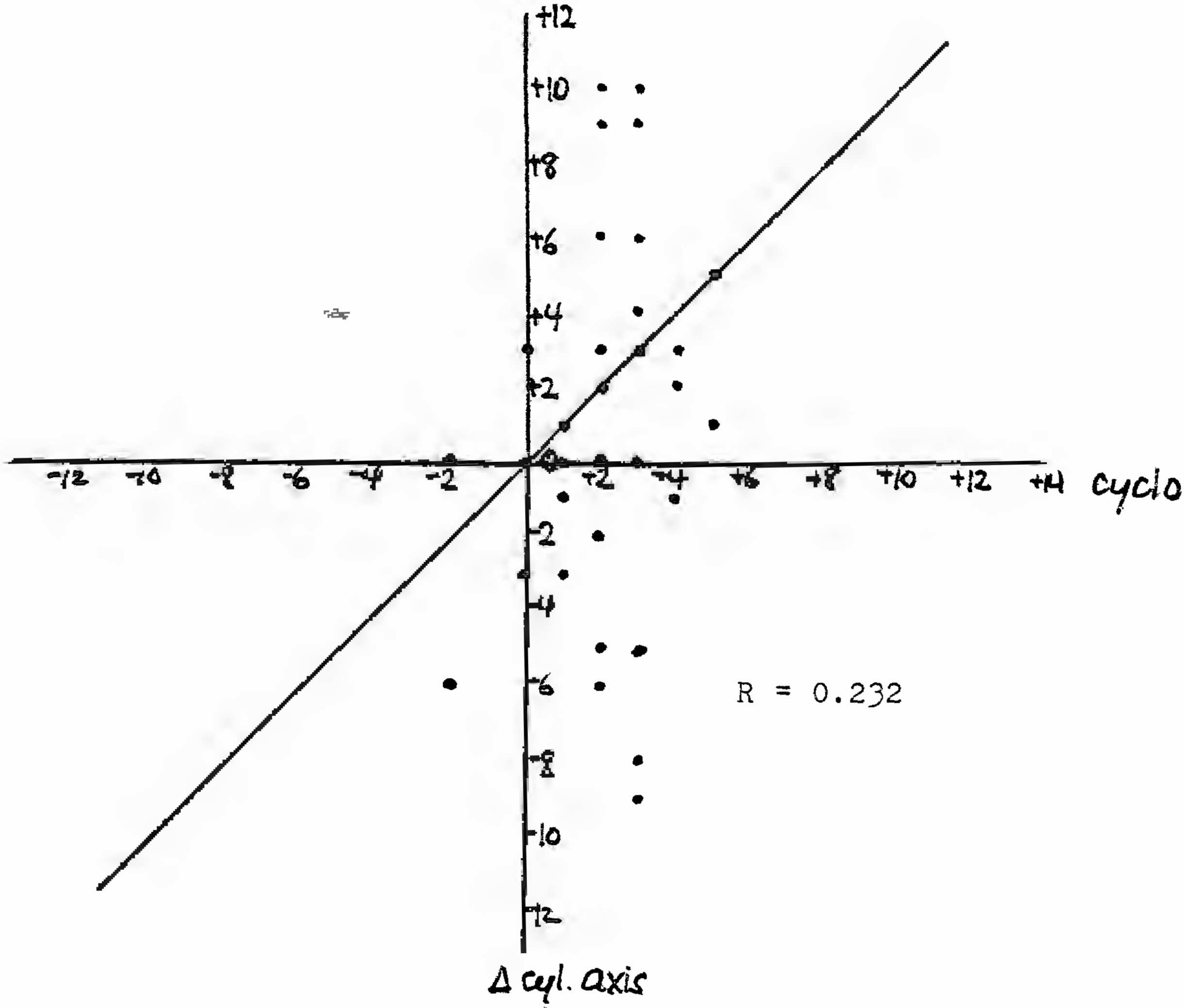

Figure 3. Table I, cylinder power 0 D. to -.75 D., cyclophoria and change in cylinder axis plotted, and correlation coefficient.

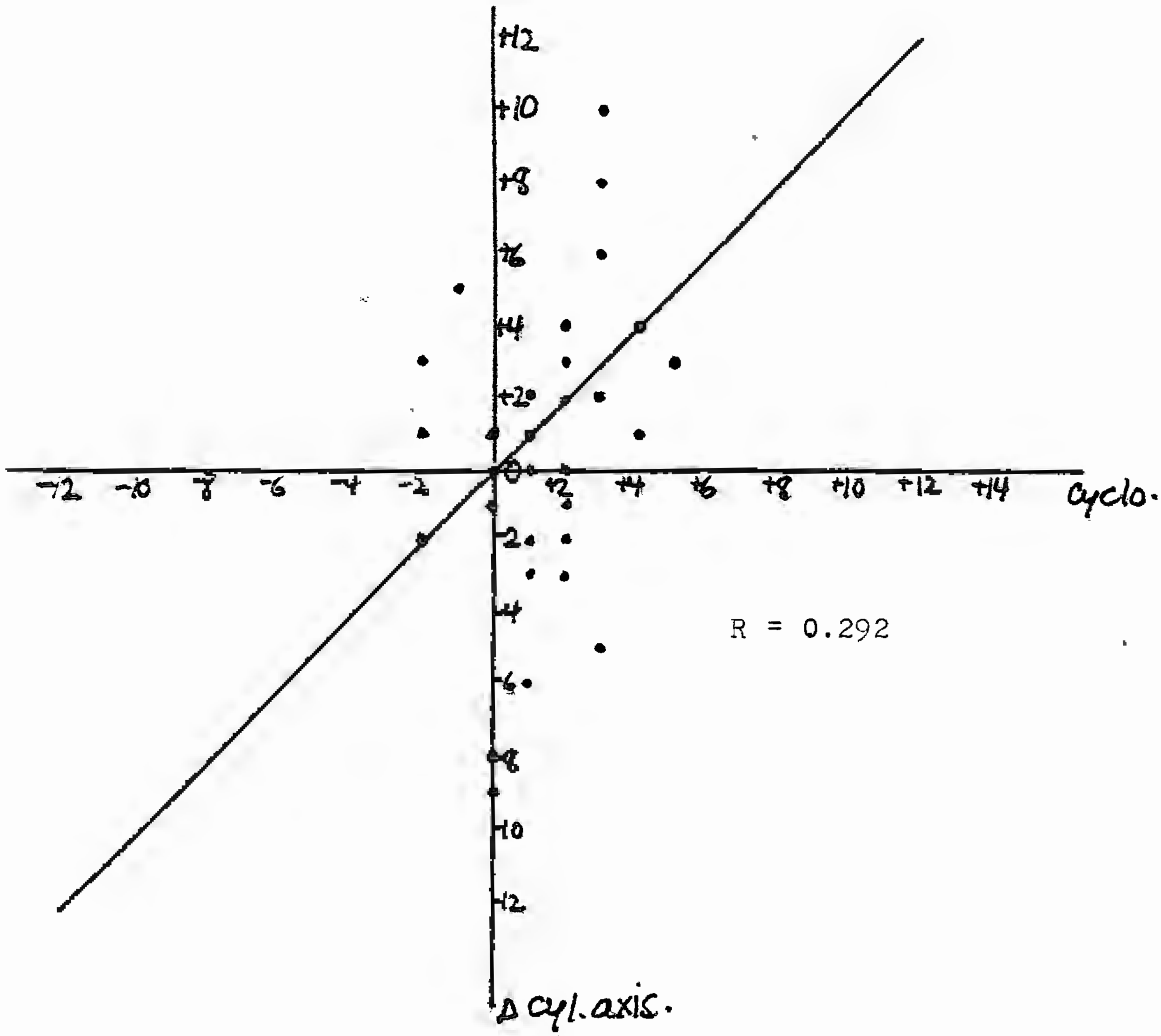

Figure 4. Table II, cylinder power -1.00 D. to -1.50 D., cyclophoria and change in cylinder axis plotted, and correlation coefficient.

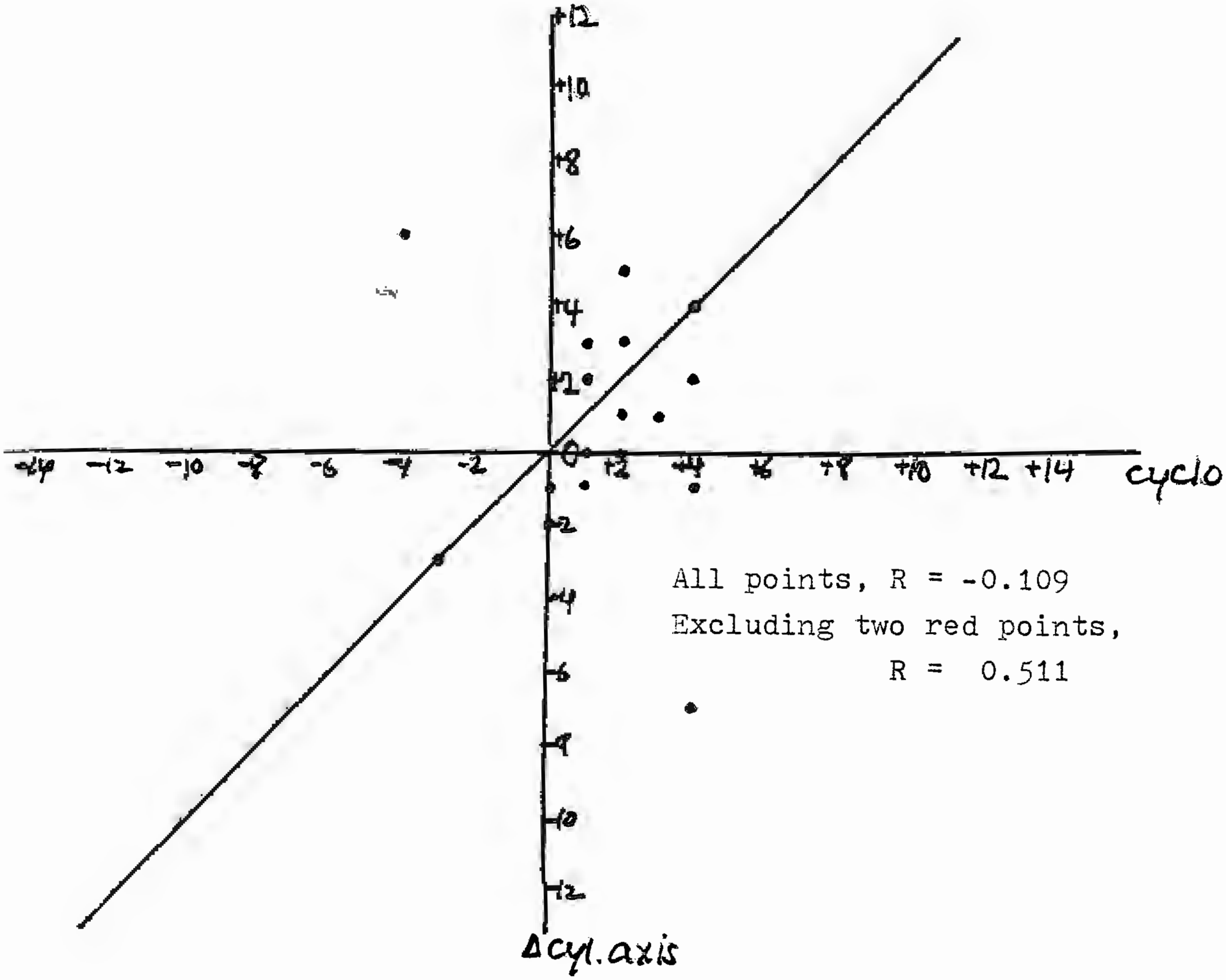

Figure 5. Table III, cylinder power -1.75 D. or more, cyclophoria and change in cylinder axis plotted, correlation coefficient for all points, and correlation coefficient excluding two points in red.

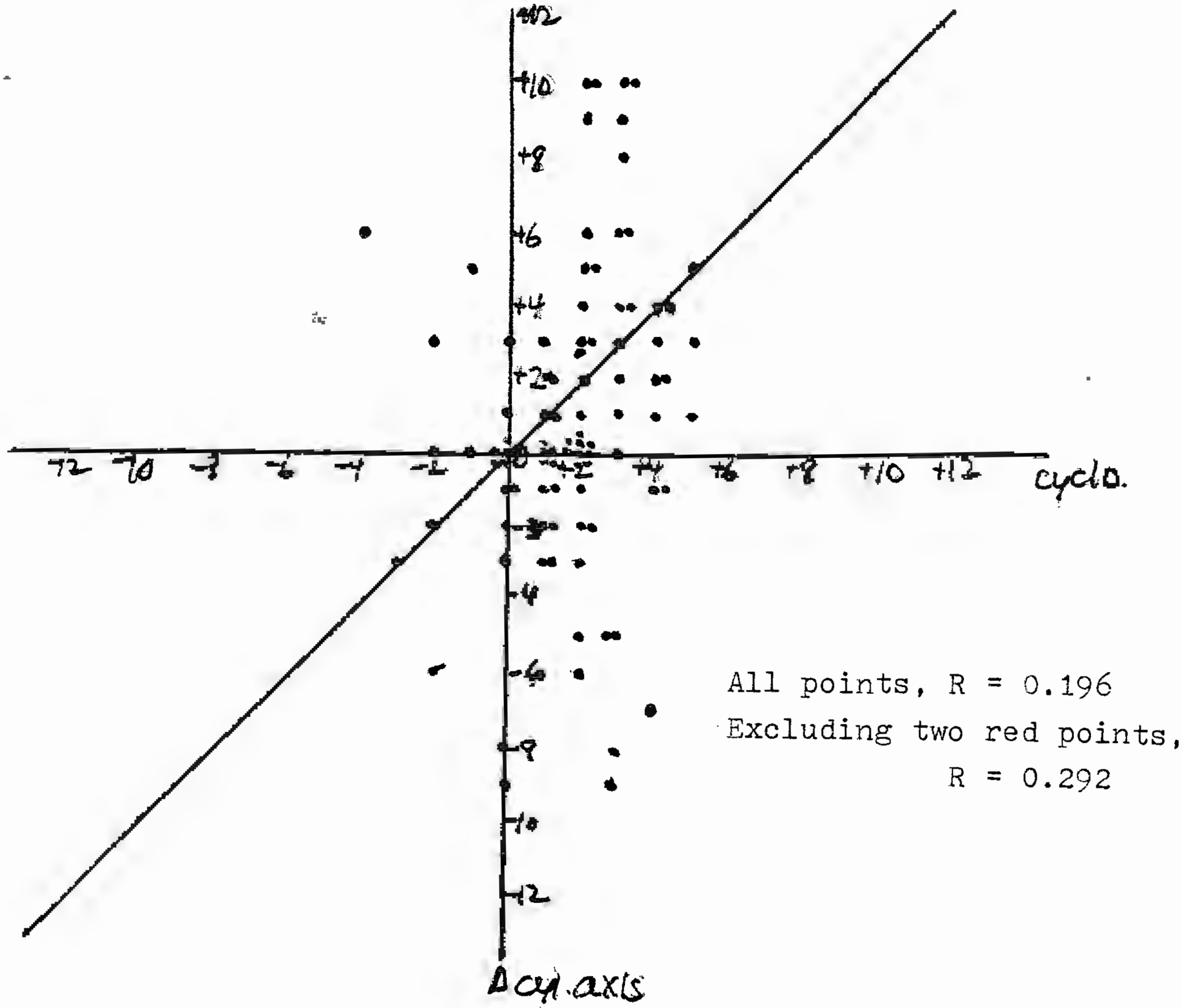

Figure 6. All points, cyclophoria and change in cylinder axis plotted, correlation coefficient for all points, and correlation coefficient excluding two points in red.

Discussion and Summary

From our results and subsequent data analysis we can formulate two general conclusions about the relationship of cyclophoria and the binocular and monocular refractions of astigmatism:

1) When considering the mean values of cyclophoria and changes in cylinder axis, we find a general tendency towards an excyclophoria which corresponds to a tendency towards an excyclorotation in the change in cylinder axis from binocular to monocular refractions in all three groups.

In all three groups we find that the mean amount of excyclophoria exceeds the mean amount of excyclorotation in cylinder axis ($+1.25^{\circ}$ to $+0.20^{\circ}$, $+1.50^{\circ}$ to $+0.85^{\circ}$, and $+1.975^{\circ}$ to $+1.05^{\circ}$).

In regards to our discussion of the variable responses of subjects to changes in cylinder axis, we note that the standard deviations of cylinder axis decrease significantly towards the groups with greater cylinder power, (4.76 to 3.75 to 3.08 from Tables I, II, and III, respectively). This is probably due to a greater reliability of the subjects with higher cylinder error on the astigmatic test, rather than any greater tendency for low astigmats to show higher cyclophoria effects. With the low astigmats, it is the variability of the subjects' sensitivity to the Pratt near cylinder test that thus prevents us from obtaining a higher correlation, because cyclophoria variations remain fairly stable in all groups.

2) When considering the correlation coefficients of the plotted data points of cyclophoria versus change in cylinder axis, we find a basically random distribution (0.196, 0.232, 0.292, and -0.109, for the sum total, Tables I, II, and III, respectively)

The best possible correlation could be derived by excluding two very deviant points off of Table III (0.511), but that is still far from a very strong positive relationship.

In summary, we can conclude from the mean values derived above that cyclophoria does definitely play a role in the shift in axis from a binocular to monocular refraction, but since the correlation coefficients concluded that these data points were so randomized, we must say that cyclophoria's influence varies in amount in each individual subject in changing the axis of astigmatism.

Because of such a random correlation between cyclophoria and the changes in axis, a cyclophoria test would probably not be an efficient indicator of what amount and direction of rotation a patient functioning binocularly would manifest. But the implications that a change in axis between a monocular and binocular refraction does occur, suggests that for patients with greater cylinder powers, where there is less tolerance for an imprecise axis measurement, a binocular refraction should be performed in order that a more functional refractive error can be determined.

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